LA-UR-21-25276
Approved for public release; distribution is unlimited.

Title:	Black Holes, Crashing Galaxies, and Strange New Planets
Author(s):	Smullen, Rachel Ann De, Soumi
Intended for:	Physics Camp Outreach Talk
Issued:	2021-06-03

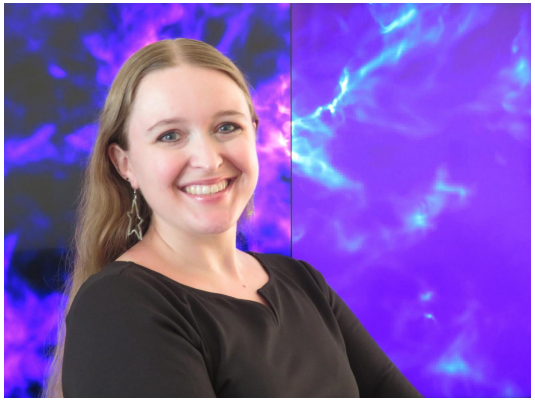
Dr. Rachel Smullen

Grew up on the west coast (CA/OR)

Physics at UWyoming (BS 2014)

Astrophysics at UArizona (PhD 2020)

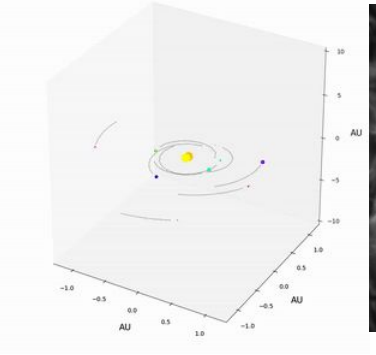
Now postdoc in computational physics @ LANL

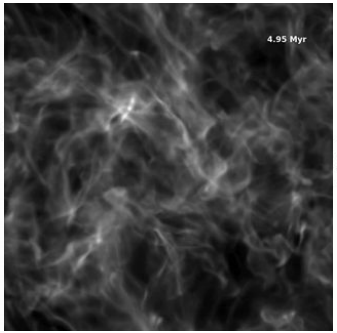


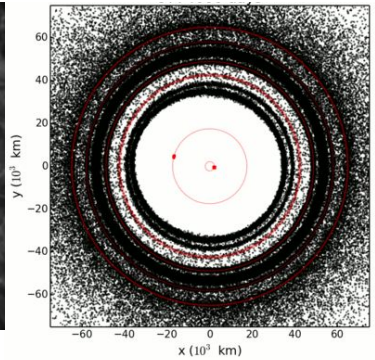
💻 rsmullen.github.io

I enjoy hiking, cooking,
reading, traveling, and more!

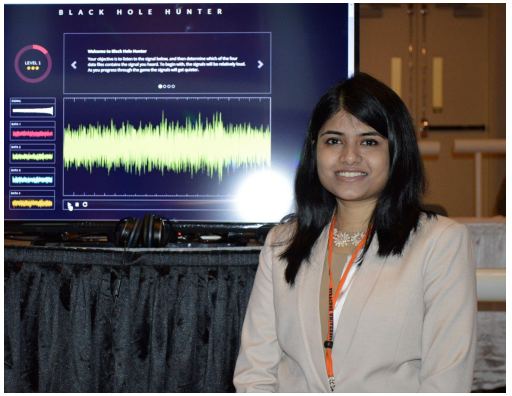
I use simulations to study how stars and planets form







Dr. Soumi De



soumide@lanl.gov

Grew up in India

Completed undergrad in Physics in India

Moved to the USA in 2015

PhD in Physics @ Syracuse University (2020)

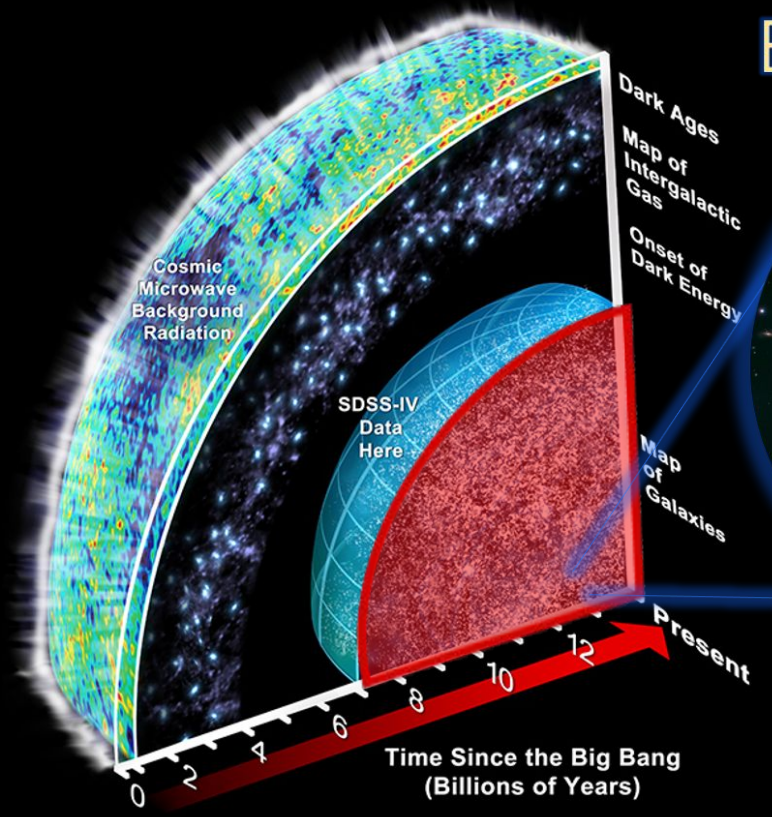
Now computational physics postdoc @ LANL

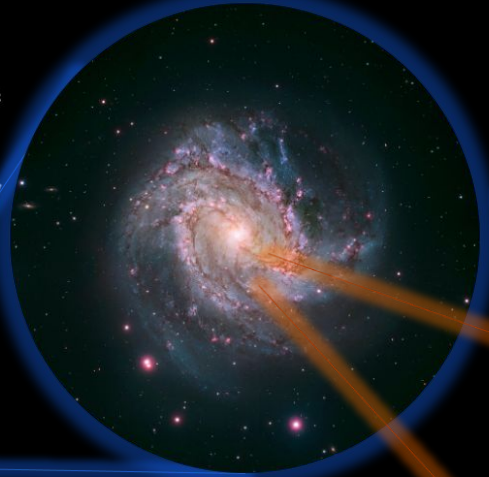
I get to learn something new everyday through my research & work with amazing scientists around the world -- this motivates me in my job

I write computer programs to hunt for black holes and neutron stars

Extragalactic astronomy

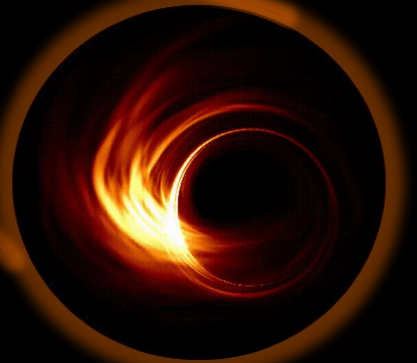
Asia (Joanna) Piotrowska
jmp218@cam.ac.uk
joanna.p_k





galaxies

NASA/ESA/STScI



supermassive black holes

Hotaka Shiokawa

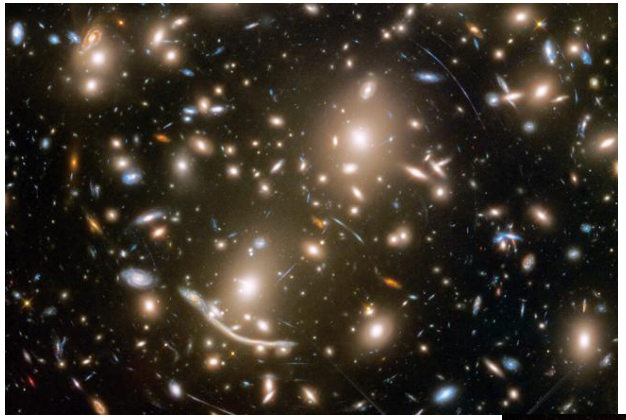
SDSS

Black Holes, Crashing Galaxies, and Strange New Planets

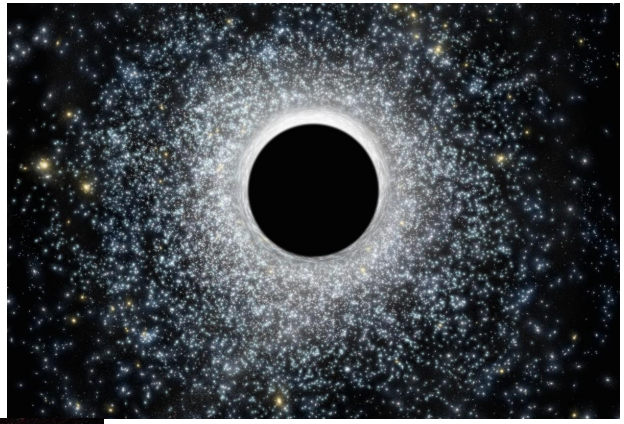
HOW SIMULATIONS HELP US UNDERSTAND OUR UNIVERSE

Rachel Smullen & Soumi De

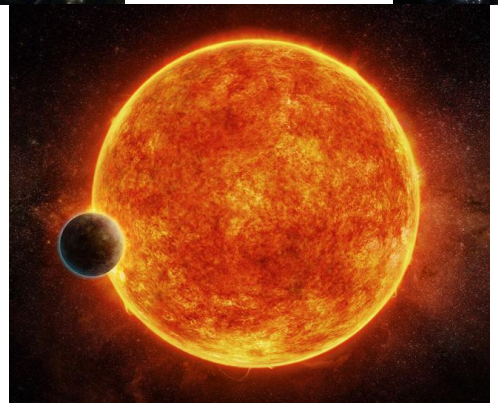
The universe is made up of many astonishing objects, such as…



Galaxies



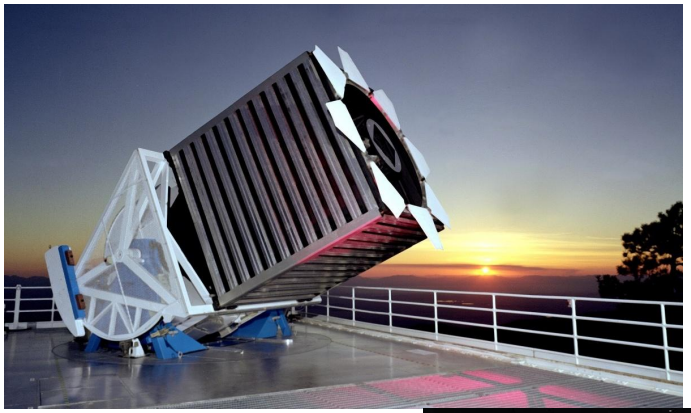
Black holes



Planets

…And so much more!

We can look out into the universe with telescopes and observatories



Galaxies

Black holes

Planets

The universe is governed by surprisingly simple physics

- Gravity
- Fluid dynamics
- Radiation
- Magnetic fields
- (Atomic) Chemistry

Simulations can help us understand how the universe works

A simulation is a "recipe" for understanding physical processes

You can think of it like a recipe for cooking or baking

What is a simulation?

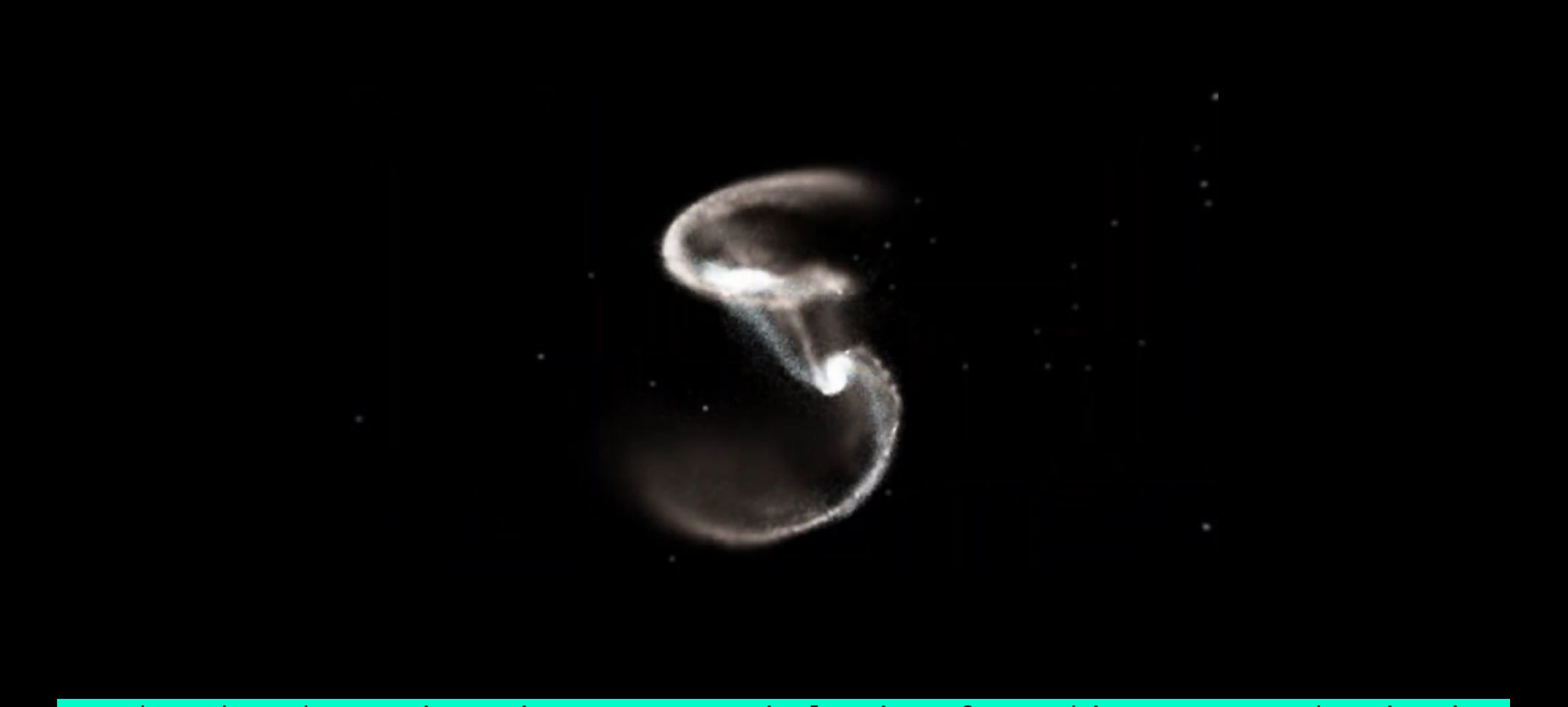
Start with ingredients	
flour, sugar, butter	stars, gas, planet(esimals)

Follow recipe to combine	
stir until combined	add in physics (e.g., gravity)

Cook/Bake	
put in oven	run on a (super)computer

COOKIES!!!	SCIENCE!!!

So... What can we do with simulations?



Remember that observations give us a very simple view of something at a snapshot in time.

Simulations allow us to study the physics and evolution of things we see in detail

Space Telescope Science Institute

We cannot see black holes directly with telescopes...

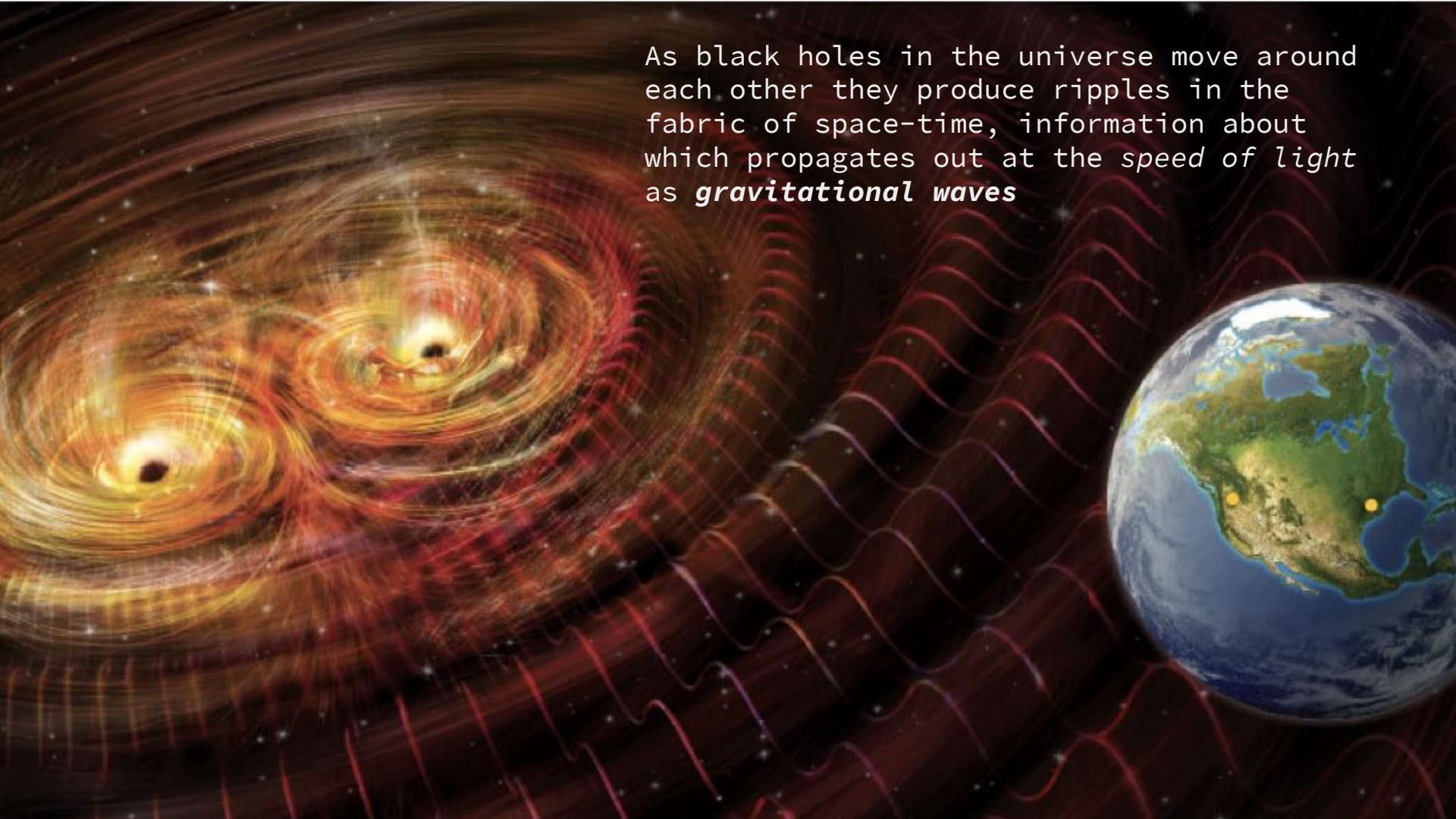
So how do we observe them and how do we understand their physics?!

Example #1:

Black Holes

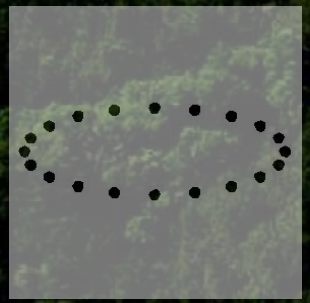
What are Black Holes?

- They are massive amounts of matter packed into a very small area.
- Think of a star ten times more massive than the Sun squeezed into a sphere approximately the diameter of your town.
- This produces a huge gravitational force which absorbs anything sufficiently close to the black hole, including light!

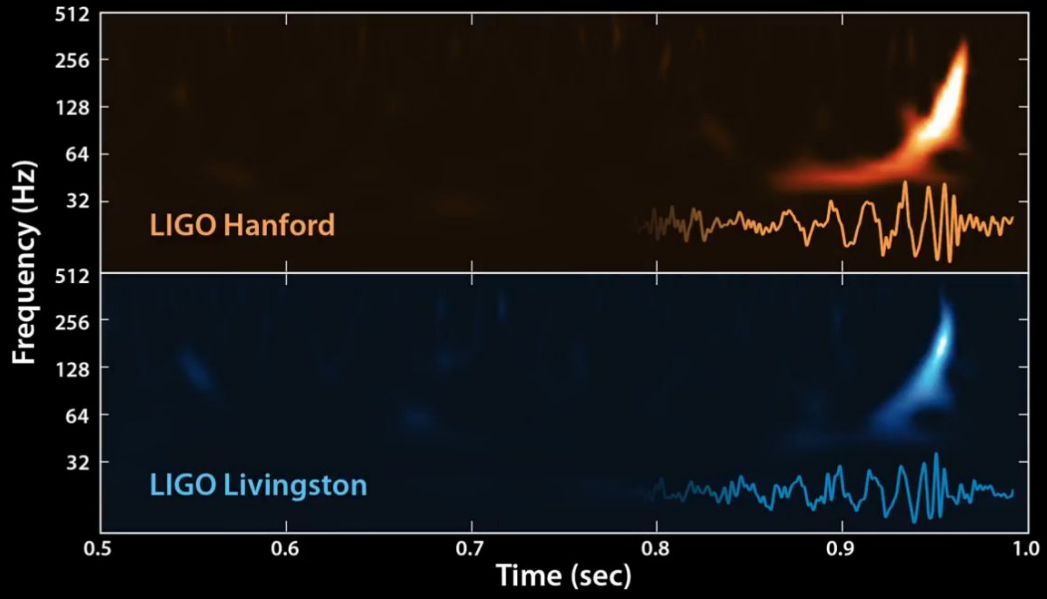

As black holes in the universe move around each other they produce ripples in the fabric of space-time, information about which propagates out at the *speed of light* as ***gravitational waves***

The LIGO observatories have the technology to detect ripples in space-time as gravitational waves squeeze and stretch the Earth by the width of a human hair

—THIS IS HOW WE OBSERVE BLACK HOLES

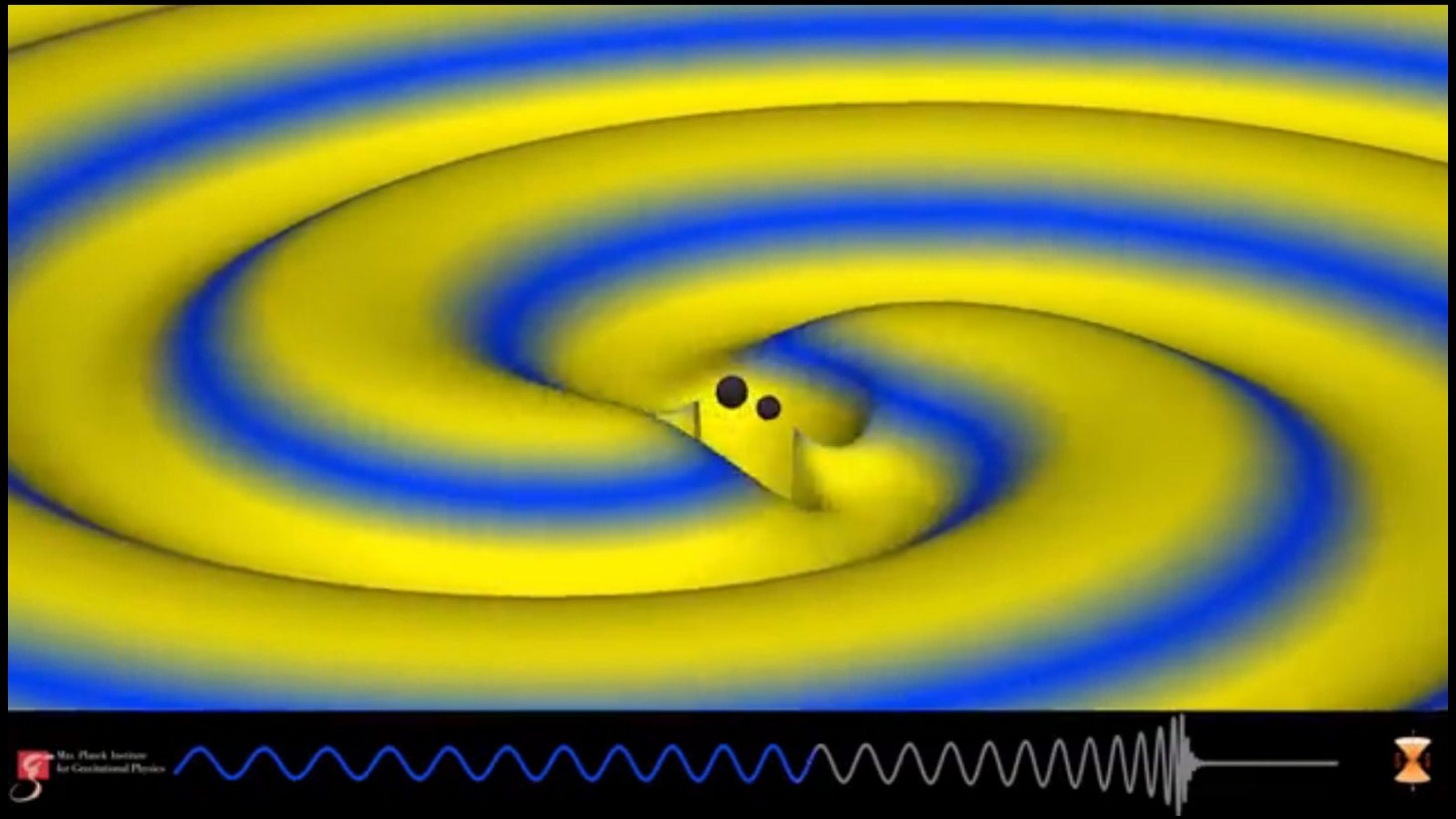


Gravitational waves show up as "blips" in the data. But what type of black holes make this signal?



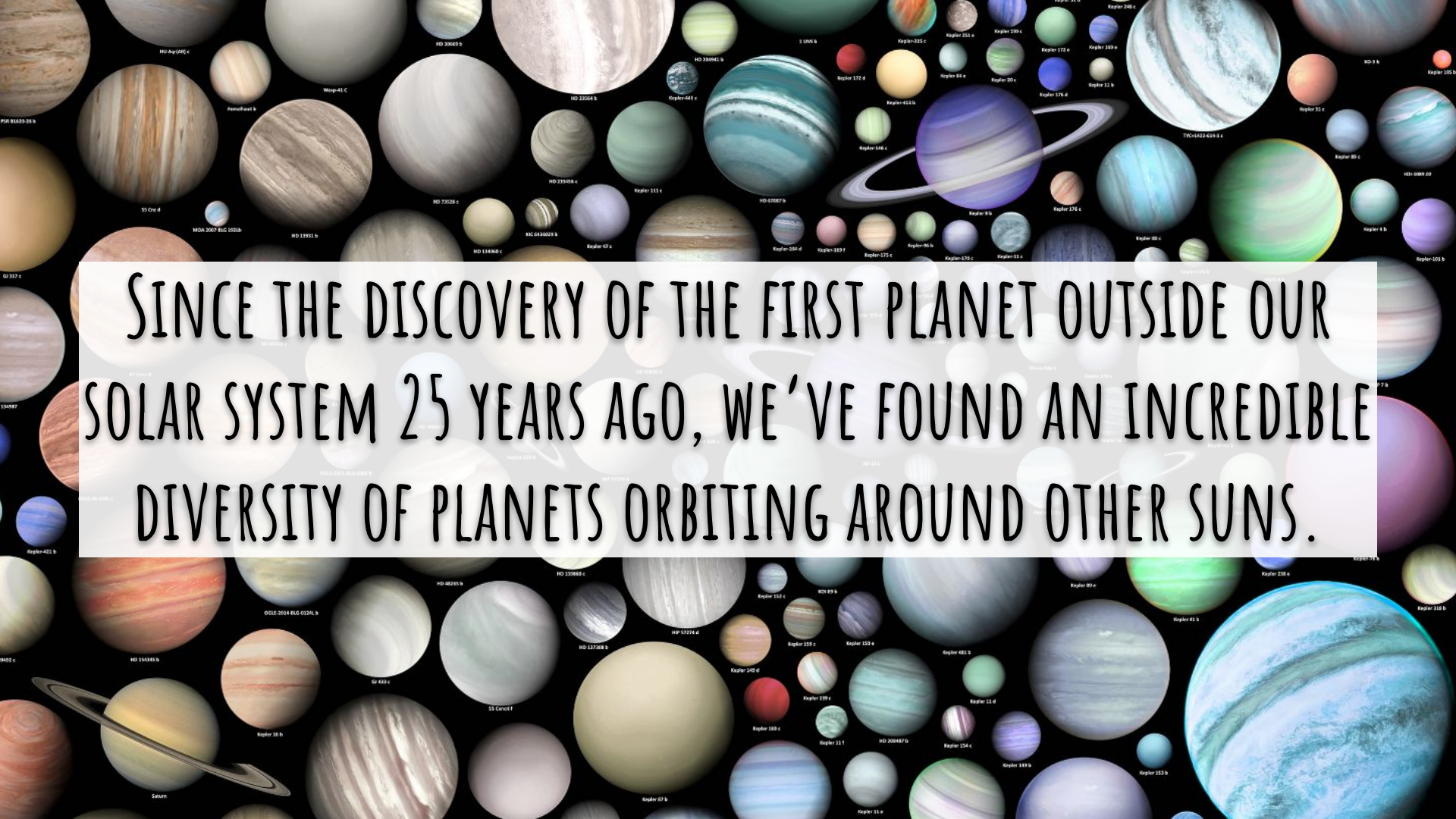
Ingredients:
Black Holes

Physics:
Gravity*



How can we learn more about planets than we can directly observe?

Example #2: Exoplanet Systems

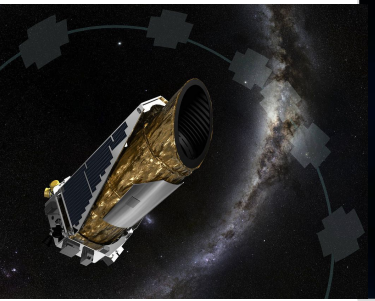

Since the discovery of the first planet outside our solar system 25 years ago, we've found an incredible diversity of planets orbiting around other suns.

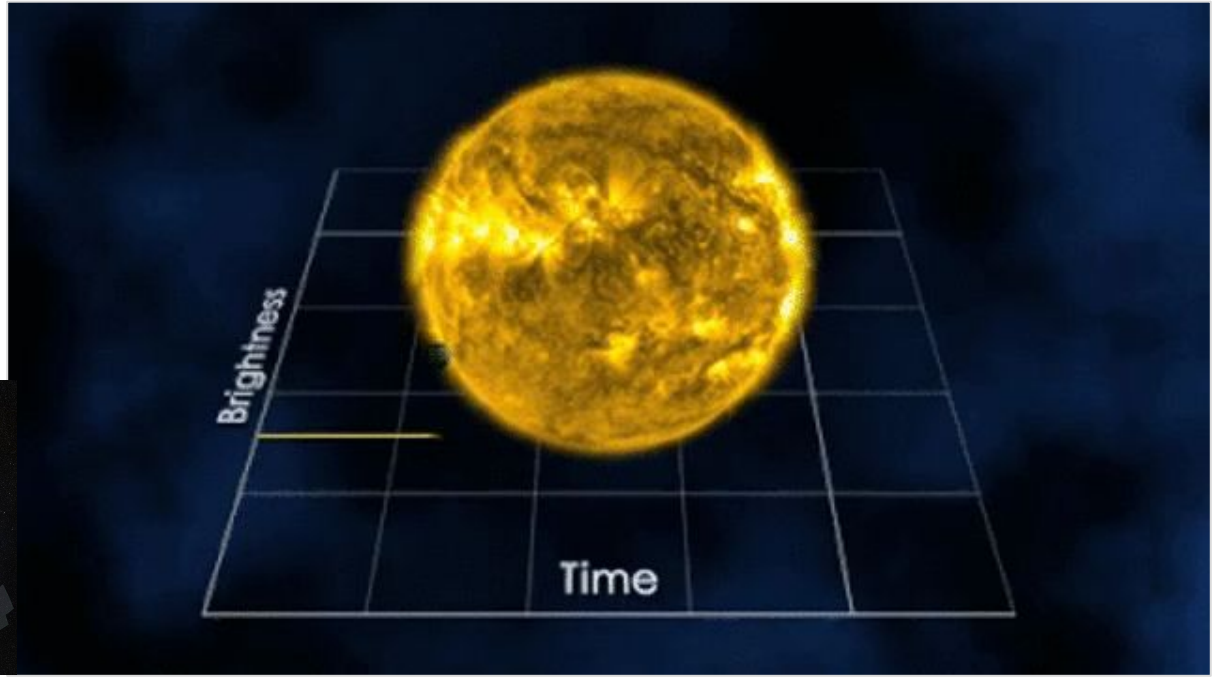
We discover exoplanets through the transit method

For the ~4000 planets discovered with transits, we get two pieces of information:

⋆The size of the planet

⋆The length of the planet’s year

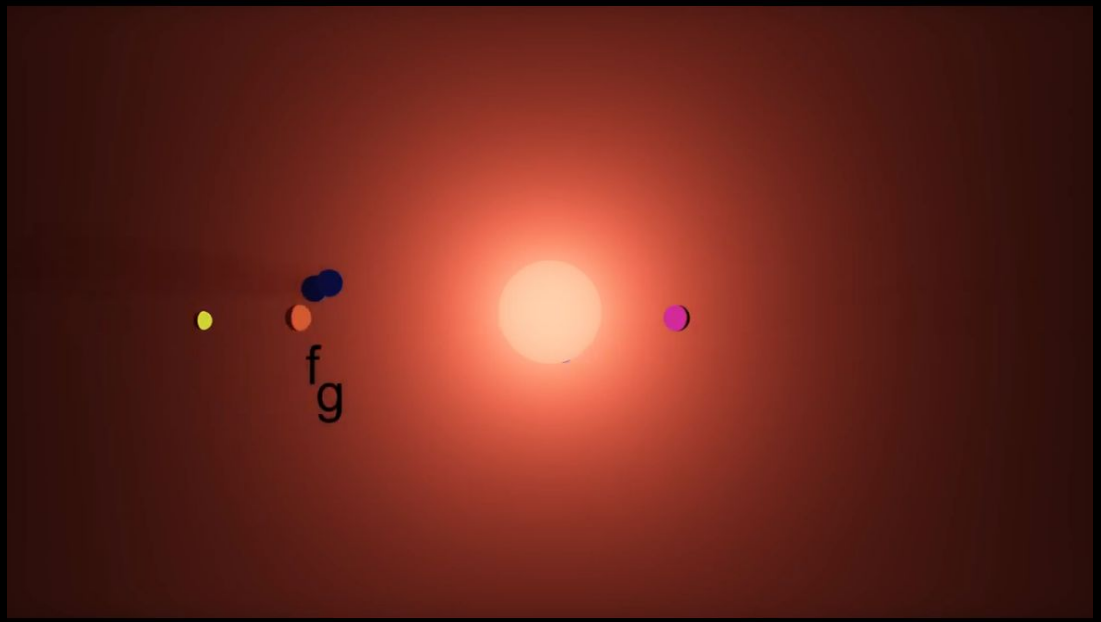




Simulations help show the interactions between planets

Ingredients: Star, planets **Physics:** Gravity

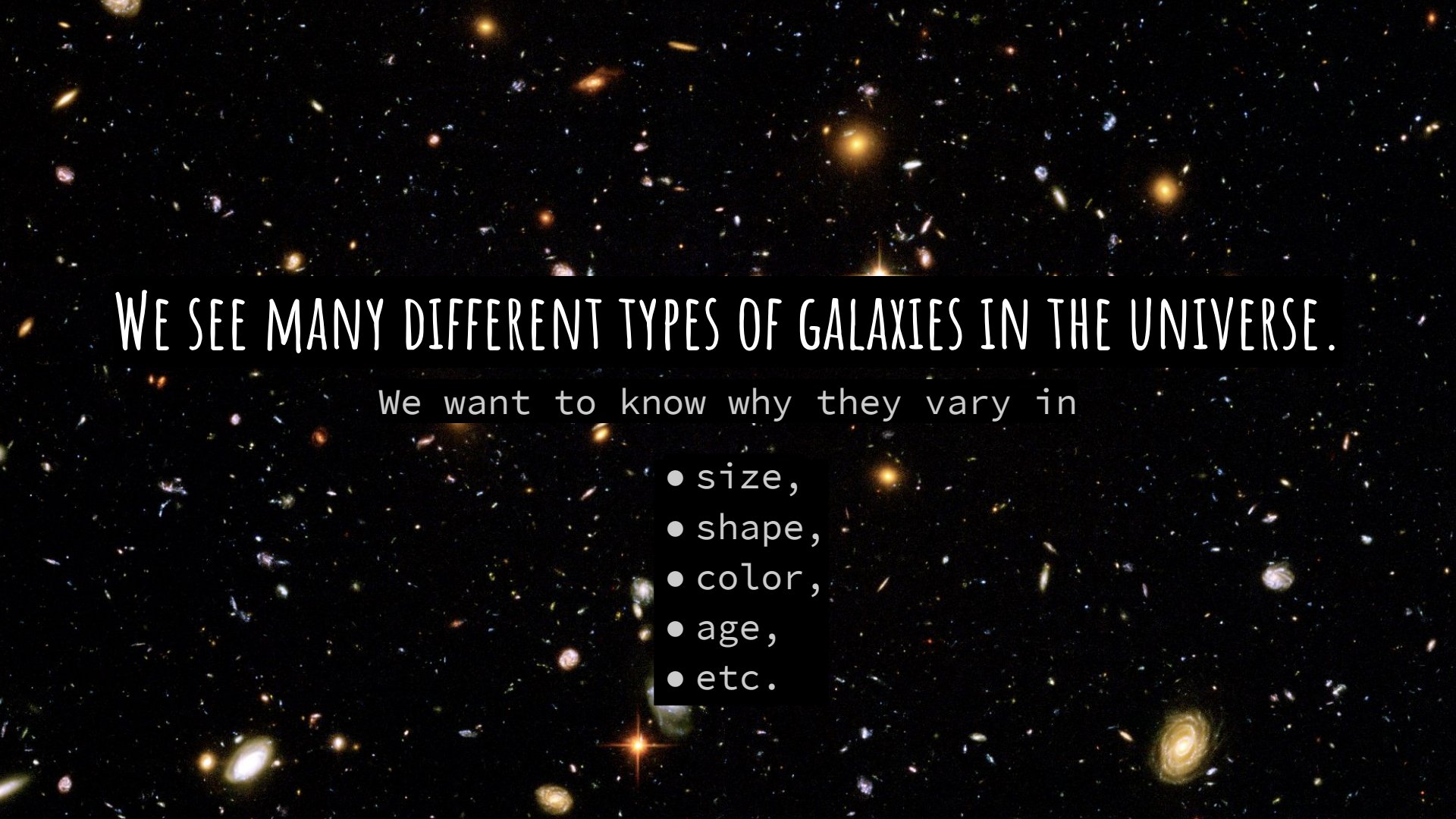
Trappist-1
7 Earth-like planets that orbit closer than Mercury



The planets are in a special configuration called *resonance*, which makes music in this simulation.

How does a galaxy evolve from the Big Bang to today?

Example #3: Galaxy Evolution



We see many different types of galaxies in the universe.

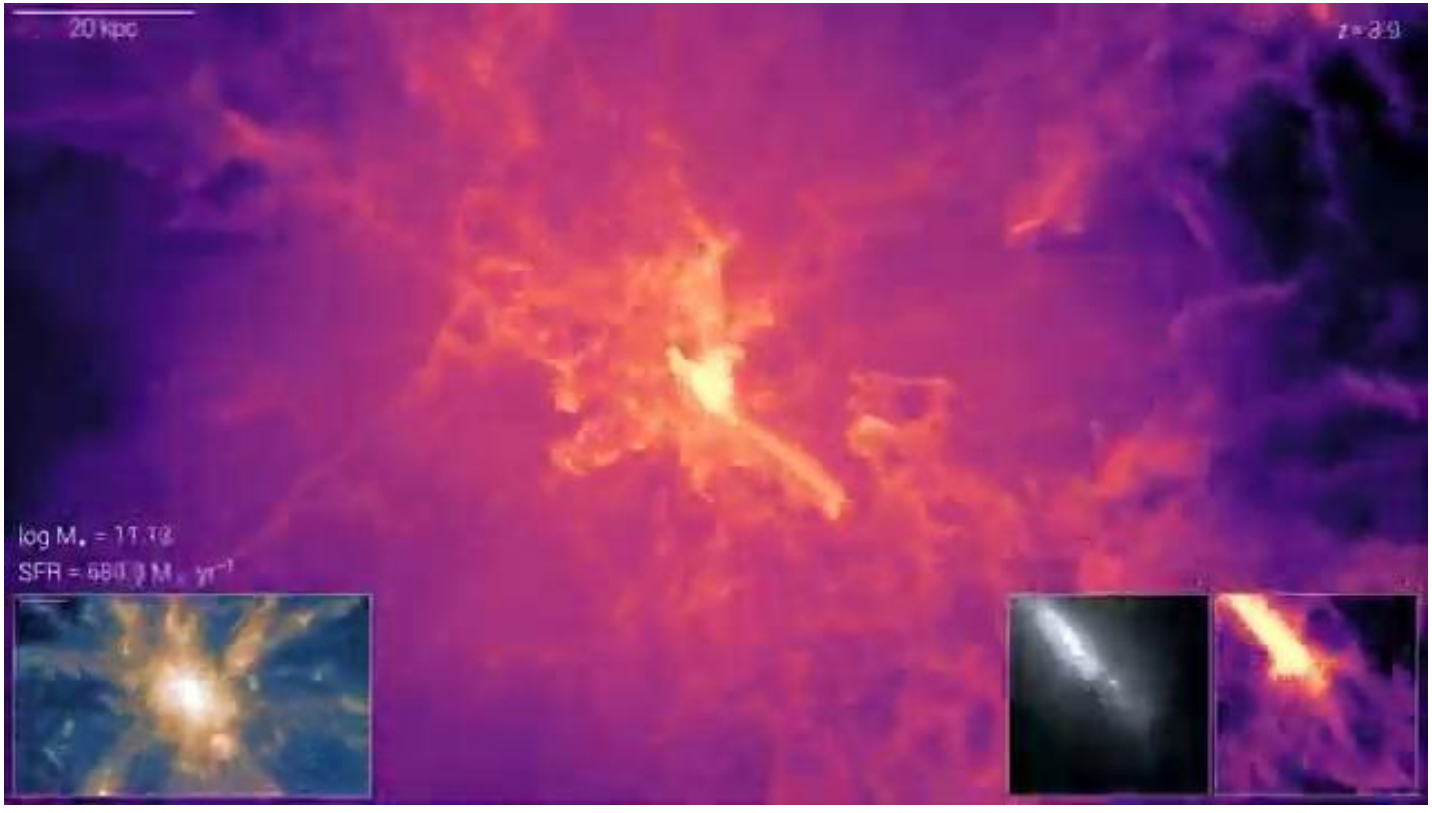
We want to know why they vary in

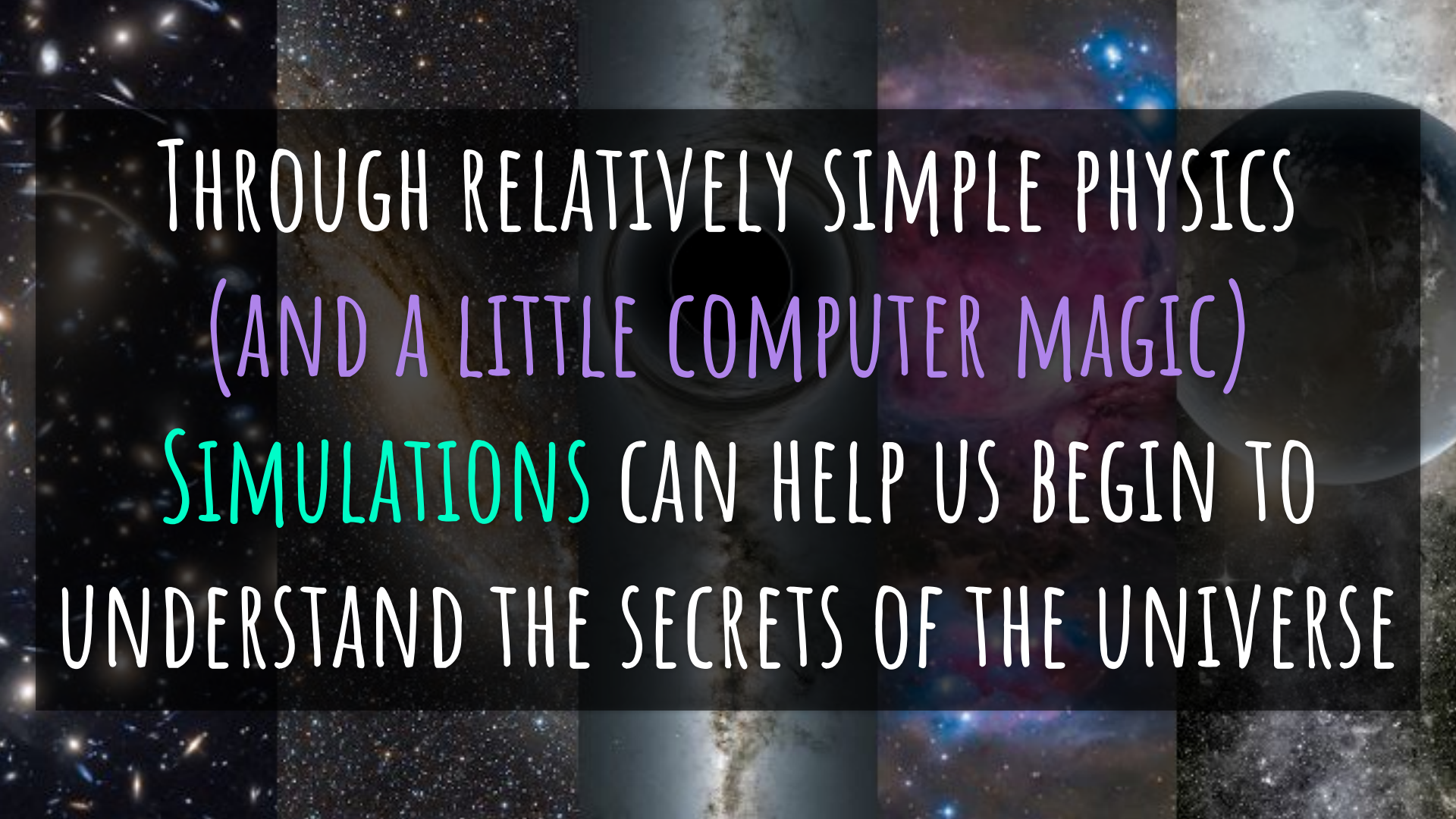
- size,
- shape,
- color,
- age,
- etc.

Simulations help us figure out the physics behind the pretty pictures

Ingredients: Gas, stars... **Physics:** Gravity, fluid dynamics, magnetic fields, radiation, chemistry

IllustrisTNG
One of the biggest *cosmological simulations* (a simulation of the universe from beginning to today) ever run

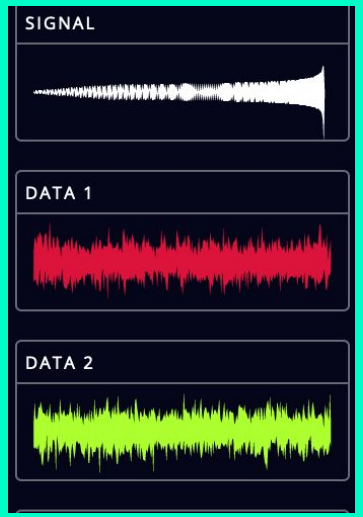



Through relatively simple physics
(and a little computer magic)
Simulations can help us begin to
understand the secrets of the universe

Let's do some science!

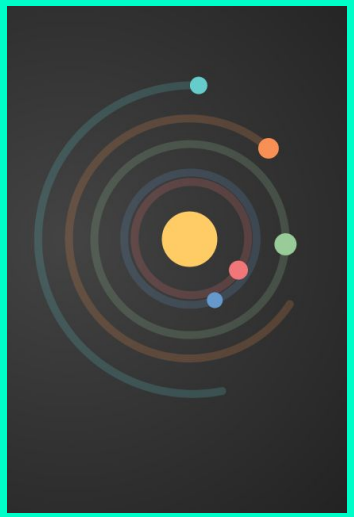
Breakout Room #1:

Find black holes in LIGO data with Soumi!



Breakout Room #2:

Make (and break) planet systems with Rachel!



Breakout Room #3:

Figure out how far away galaxies are with Asia!